Analogous Bioclimates and introduction of Economic Exotics

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(*With nine text-figures*)

The methods generally used to derive the climatic analogies are reviewed and the results obtained by Thornthwaite's system by previous workers are critically analysed. The bioclimatic methods of Gaussen are developed to establish the homoclimatic counterparts of the stations of the dry tracts of the Indian sub-continent.

Introduction

Bioclimate may be defined as the climate in relation to life. One of the aims of applied bioclimatology is to establish the analogous climates of the world for the exchange of economic plants. The need for the introduction of more food-, fruit-crops and those providing raw materials for industries is at the moment more pressing than ever.

Although India is rich in timber species, introduction of some woods of special quality is desirable. For instance, the wood of *Ocotea rodiaei* Mex. is very useful in sub-marine construction as it resists the attack of the marine worm *Teredo*. *Ochroma lagopus* Swartz. has a very light wood used in the construction of aeroplanes. Both these species are natives of tropical America and they may be successfully tried in suitable parts of peninsular India. This part of the sub-continent suffers from the scarcity of conifers too ; trials of pines of S.E. Asia and Central America (*Pinus merkusii* Jung., *P. insularis* Endle., *P. tropicalis* More., *P. occidentalis* Swartz., *P. montezumae* Lamb. etc.) may yield encouraging results.

It is on record that an economic species has become better established in the country of its introduction than in its indigenous area. Zanzibar is the principal producer of the clove (followed by Penang, Madagascar and Indonesia) though the original home of the clove tree [*Eugenia caryophyllus* (Spreng.) Bullock and Harrison] is the Moluccas. The rubber tree (*Hevea brasiliensis* Muell) transported from S. America to Malaysia, helped towards the unemployment problem. The local labour being insufficient, it brought about migrations from India and China.

One can go on multiplying examples of such economic plants which may be profitably introduced in the Indian sub-continent with its wide range of climates (*see* Meher-Homji 1963).

Attempts made to derive the homoclimates may be grouped into three categories :

(1) Physical and meteorological methods using climatic formulae, indices and coefficients.

(2) Diagrammatic representations, examples : hydrothermic figure (Raunkiaer 1908), clima-diagram (Chaptal 1933), agro-climate diagram (Azzi 1954), hythergraph (Taylor 1920a, b), ombrothermic diagram (Bagnouls & Gaussen 1953) and the modified version of the latter ' klima-diagramme ' (Walter 1955a, b).

(3) Biological criteria to reflect the climatic analogies : (*a*) floristic (systematic, floral elements) ; (*b*) ecological (hydrophyte, xerophyte in relation to water ; megatherms, microtherms for temperature ; heliophyte, sciaphyte for light) ; (*c*) vegetational [growth-forms of Humboldt (1805) and Grisebach (1884) ; life-forms of Raunkiaer (1908), physiognomy and structure]. Of all these biological criteria, only the vegetation types based on the characteristics of physiognomy and structure are shown to reflect the climatic similitudes (Meher-Homji 1963).

In the first category may be cited the formulae of Transeau (1905), Penck (1910), Köppen (1900, 1918), Lang (1920), de Martonne (1926) and Thornthwaite (1933, 1948) among others. Only the later work of Thornthwaite has been frequently used to derive the climatic homologies; Nuttonson (1947a, b, c, 1951) has used it to seek climatic analogies between parts of Asia, Europe and North America; Melwyn Howe (1960), Kaushik *et al.* (1969) and Subrahmanyam & Sastry (1969) have applied the method to establish the homoclimatic counterparts of certain stations of India.

Comments on results obtained by Thornthwaite's method

None of the above formulae have given absolutely satisfactory results to explain the vegetation types of India (Bharucha & Shanbhag 1957 ; Meher-Homji 1963, 1967).

Some analogies are questionable in the works of the followers of Thornthwaite's system.

(1) Melwyn Howe (1960) on the homoclimes within the British Commonwealth.

(*a*) In the prehumid climate with little or no water deficiency (*Ar*), certain tropical stations of India and Ceylon, Ootacamund and Rangalla for example, are shown to have the same formula (B'_1 *a*) as Buxton (England) and Clayoquot (British Columbia), stations having a temperate climate.

In the opinion of this author, the altitude of Ootacamund may compensate the latitude factor for the temperature, at least partly[1], but not for the photoperiod.

(*b*) In the humid climate (*Bir*) with little or no water deficiency, it is surprising to see a dry station like Karachi placed together with Gauhati (India), Kuala Lumpur (Malaysia) and Belize (Honduras).

(*c*) In the arid climate (*E*), Jodhpur having summer rains and Peshawar having an irregular regime of rains are classified together (*A′ a′*).

(2) Kaushik *et al.* (1969) on the homoclimates of the arid and semi-arid zones of India.

(*a*) Sri Ganganagar is equated to Dera Ismail Khan, Khushab and Lyallpur (arid *Ed*, second megathermal climate *A′* 2′).

However, the last two stations have 10 months dry and 257 to 266 biologically dry days. Sri Ganganagar has 11 months dry with 280 dry days and Dera Ismail Khan 12 months dry with 300 biologically dry days, according to the classification of Bagnouls & Gaussen (1957).

Further, the ratio of the cold season (Nov. to March) precipitation to that of the hot season (May-Sept.) is 1 : 3·4 for Sri Ganganagar and Khushab, whereas 1 : 5 for Lyallpur and 1 : 2 for Dera Ismail Khan ; this low ratio suggests an irregular regime for Dera Ismail Khan (62 mm. of winter and spring rains ; 137 mm. of summer rains). For the remaining stations, the ratios indicate a tropical tendency.

(*b*) In the third megathermal (*A′* 3) type, Sirsa and Hissar (*a*2′) are compared to Sibi, Multan, Montgomery, Jacobabad, Sukkur of West Pakistan and Insalah of Algeria.

The contrasting points are :

—Hissar has an annual average rainfall of 425 mm. but Jacobabad, Sukkur and Insalah receive less than 100 mm. and Sibi 117 mm.

—Hissar has 9 months dry with 237 biologically dry days ; excepting Montgomery (11 months dry), the remaining stations experience a dryness of 12 months (with over 290 days biologically dry). Insalah may not receive any rain certain years and is classified as *true desertic* by Emberger, Gaussen *et al.* (1962-63) with over 355 dry days. Hissar on the other hand is shown as subdesertic with tropical régime.

Tropical tendency is also observed for Multan, Montgomery, Jacobabad and Sukkur but not for Sibi having 64 mm. of summer precipitation against 59 mm. of winter and spring (irregular régime).

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[1] Thermic amplitude i.e. the difference between the mean temperature of the hot test and the coldest months is very low (about 4°C) for the altitudinal stations of south India ; it is about 15°C for the stations of temperate latitude. On the other hand, the diurnal range of temperature is very important for the tropical montane stations.

(*c*) In the *Ed*, *A*′ 3, *a*3′ type of climate, Jodhpur, Khanpur, Las Bela, Ormara, Hyderabad (W. Pakistan), Wadi Halfa and Bilma are placed together.

OMBROTHERMIC DIAGRAMS

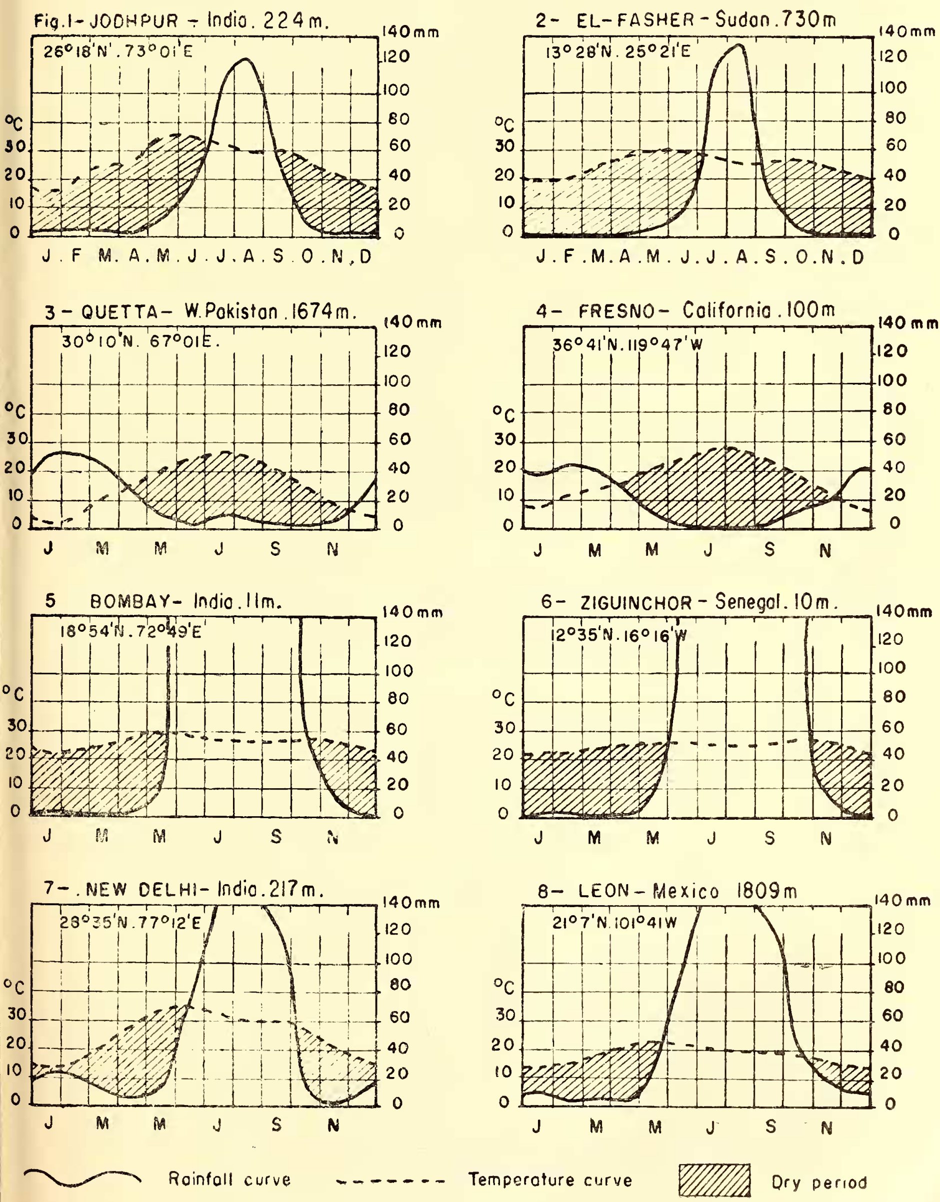
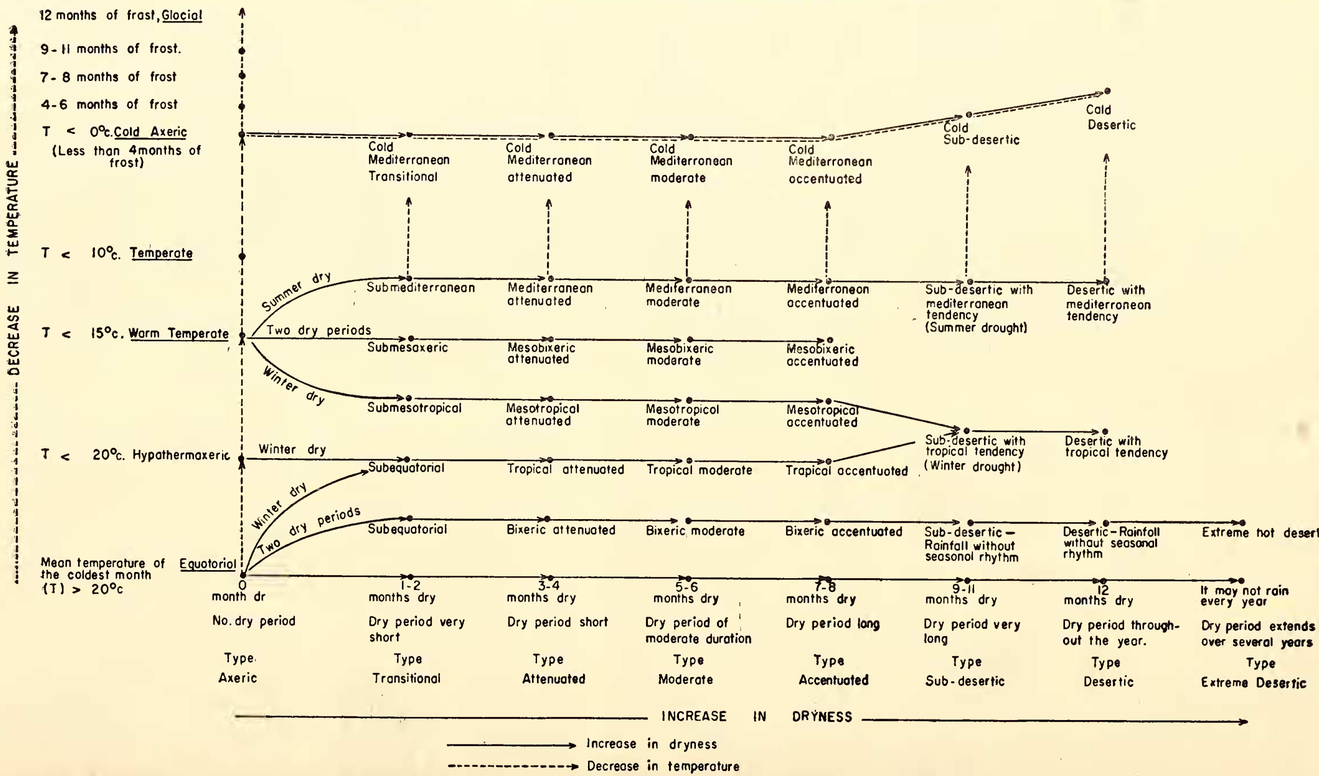


Fig. 9

DIAGRAMMATIC REPRESENTATION OF THE CLASSIFICATION OF BIOLOGICAL CLIMATES OF BAGNOULS AND GAUSSEN (1957)



As a matter of fact, Wadi Halfa (Sudan) and Bilma (W. Africa) have a *true desertic* climate with 360 biologically dry days like Insalah (Emberger, Gaussen *et al.* 1962-63). Ormara shows mediterranean tendency with 117 mm. (i.e. 76% of total rainfall) in winter and spring, and just 20 mm. (13%) in summer. Jodhpur comes near Hissar—subdesertic with tropical tendency (9 months dry, 262 dry days).

Were it not for the régime, the olive tree (*Olea europaea* L.) of the subdesertic parts of North Africa (with mediterranean climate) would thrive in the dry parts of Rajasthan.

(*d*) In the fifth megathermal class (A' 5), the analogy pointed out between Bellary and Aden is too far fetched. Bellary has an annual average rainfall of 509 mm. whereas Aden receives only 44 mm.

(3) Subrahmanyam & Sastry's (1969) climatic analogues for the dry zone of India.

(*a*) Nagpur is classified in the category of dry sub-humid climate (C_1) having no adequacy of moisture at any time of the year (C_1 d) but Seoni situated in the vicinity of Nagpur is placed in the category of large summer water surpluses (C_1 W_2). However, the total of the average April-October rainfall is hardly about 100 mm. more for Seoni (1278 mm., as against 1180 mm. of Nagpur).

The differences in the temperature of these months are also not marked. At Seoni the mean monthly temperature varies from 24°C (October) to 32°C (May) and at Nagpur from 26·5°C (Oct.) to 35·3°C (May). Besides the vegetation in the Nagpur-Seoni tract is of the same type,—a dry deciduous teak forest.

(*b*) Visakhapatnam and Coimbatore are both classified together in the semi-arid climate (Dd, A' 4, a' 9), though the former has 962 mm. of annual rainfall and 6 months dry and the latter only 590 mm. and as many as 9 months dry.

(*c*) Finally, the non-recognition of distinct régimes for Trincomalee, Jaffna of Ceylon (tropical dissymetric), Halfeka, Cyprus (Mediterranean) and Cambridge, England (temperate-atlantic) in the class C_1 S_2 (large winter water surplus) is unfortunate.

Bioclimatic Methods

One of the simplest methods to bring out analogous climates would be to compare the curves of mean monthly precipitation and temperature of various stations on a graph. The greater the resemblance in the graphs, the more analogous would be the climates. Some examples are provided in Figs. 1 to 8. The similarity in the pairs of diagrams is striking ; the diagram on the left belongs to a station of the Indian subcontinent, that on the right is a station of another country.

These graphs are in fact the ombrothermic diagrams of Bagnouls & Gaussen (1953). The abscissa bears January as the first month for the stations of the northern hemisphere but July for the southern hemisphere. Thus the stations are rendered comparable between the two hemispheres. The dry period is also depicted on the diagram by hatches according to the definition of these authors that a month is dry when its average precipitation (in mm.) is less than twice its mean temperature (in °C) : $P<2T$. The precipitation and temperature values are the results of the averages of several years and so of course the inter-yearly variability which may be important in certain cases is not considered. Another disadvantage of comparison of climates by diagrams is that only relatively few stations show a strict similarity in the precipitation and temperature curves. Therefore analogy by means of diagrams alone is not possible and there arises the need of a classification. Bagnouls & Gaussen's (1957) classification of biological climates is presented in a diagrammatic form by this author in Fig. 9. Within the framework of this broad classification based mainly on the rhythms of precipitation and temperature, a further climatic analogy may be reached by resemblances in the temperature, rainfall and length of the dry season classes.

The factor of temperature is indicated by the letter (t). Gaussen (1949) distinguishes 6 principal classes of temperature on the basis of the mean temperature of the coldest month (m) of the year which is a limiting factor for the vegetation, or of the hottest month (M) of the year. The values of the classes of temperature modified from those of Gaussen are given below :

t_1	: $M<10°C$
$t_{1/2}$	: $M>10°C$. $m<-15°C$
t_2	: $M>10°C$. $m<-5°C$
t_3	: $-5<m<0°C$
$t_{3/4}$	: $0<m<10°C$
t_4	: $10<m<15°C$
$t_{4/5}$	: $15<m<20°C$
t_5	: $m>20°C$. Mean annual $<30°C$
t_6	: Mean annual $>30°C$

The factor of precipitation is designated by the letter 'S' and its values as modified from the scale of Gaussen (l.c.) are :

S_1	: >3000 mm. of annual precipitation
$S_{1/2}$	: 2500 to 3000 mm. of annual precipitation
S_2	: 2000 to 2500 ,, ,, ,, ,,
$S_{2/3}$	: 1500 to 2000 ,, ,, ,, ,,
S_3	: 1250 to 1500 ,, ,, ,, ,,

$S_{3/4}$	:	1000 to 1250 mm. of annual precipitation
S_4	:	750 to 1000 ,, ,, ,, ,,
$S_{4/5}$	:	500 to 750 ,, ,, ,, ,,
S_5	:	250 to 500 ,, ,, ,, ,,
$S_{5/6}$	:	100 to 250 ,, ,, ,, ,,
S_6	:	< 100 ,, ,, ,, ,,

The dry period is indicated by the letter 'X'. The dryness is expressed in number of dry months ($P<2T$). The values of the classes of 'X' are :

X_1	:	1 month dry
$X_{1/2}$	:	2 months dry
X_2	:	3 ,, ,,
$X_{2/3}$	:	4 ,, ,,
X_3	:	5 ,, ,,
$X_{3/4}$	:	6 ,, ,,
X_4	:	7 ,, ,,
$X_{4/5}$	:	8 ,, ,,
X_5	:	9 ,, ,,
$X_{5/6}$	:	10 ,, ,,
X_6	:	11 to 12 months dry

In the cold climates, the frost period should also be taken into account.

Results obtained with reference to the dry tract of the Indian sub-continent

The above bioclimatic methods are applied here to bring out those stations of the world which have climates analogous to the stations of the dry tracts of the sub-continent (Table 1). Evidently the dry bioclimates fall within several categories (desertic, subdesertic with tropical, mediterranean, irregular régimes ; mediterranean and tropical accentuated types with 7 to 8 months dry) as may be seen in Table 1.

In the first column of this Table is presented the bioclimate according to the biological classification of climates of Bagnouls & Gaussen (1957) and in the second column the value of each ecological factor. Stations and their respective countries figure in columns 3 and 4. Latitude, longitude form columns 5-6. The latitude factor is of particular interest as a representative of the photoperiod ; it may account both for the intensity and duration of light. In the last column is presented the vegetation type of the station according to Champion (1936) for the stations of the Indian sub-continent and according to Schimper & Von Faber (1935) and Dansereau (1957) for the other stations.

Stations falling within the same biological climate (or bioclimate) imply a general analogy. Further precision is given by the values of the temperature, precipitation and the length of the dry season classes pointing out the degrees of similitude.

TABLE 1

BIOCLIMATES OF THE STATIONS OF THE DRY TRACTS OF THE INDIAN SUB-CONTINENT AND STATIONS HAVING ANALOGOUS BIOCLIMATES IN THE WORLD

Bioclimate (1)	Value of each ecological factor (2)	Station[1] (3)	Country (4)	Latitude (5)	Longitude (6)	Vegetation (7)
Hot desertic with mediterranean tendency (winter rains)	t_4 S_6 X_6	*Nokkundi*	W. Pakistan	28° 49′N	62° 45′E	Desert
	,,	Helwan	UAR	29° 52′N	31° 20′E	,,
	,,	Abbasia	,,	30° 5′N	31° 17′E	,,
	,,	As Salman	Iraq	30° 5′N	44° 3′E	Semi-desert
	$t_{4/5}$ S_6 X_6	Lima	Peru	12° 05′S	77° 03′W	Desert
	t_6 $S_{5/6}$ X_6	Massaoua	Erytrea	15° 36′N	39° 27′E	,,
Hot desertic with tropical tendency (Summer rains)	$t_{3/4}$ $S_{5/6}$ X_6	El Paso	USA	31° 47′N	106° 30′W	,,
	,,	Mendoza	Argentina	32° 53′S	68° 50′W	,,
	,,	*Gilgit*	Kashmir	35° 55′N	74° 23′E	,,
	t_4 $S_{5/6}$ X_6	*Bahawalpur*	W. Pakistan	29° 24′N	71° 47′E	,,
	,,	*Khanpur*	,,	28° 39′N	70° 41′E	,,
	,,	*Multan*	,,	30° 12′N	70° 31′E	Thorn forest
	t_4 S_6 X_6	*Jacobabad*	,,	28° 17′N	68° 27′E	Desert
	$t_{4/5}$ $S_{5/6}$ X_6	*Las Bela*	,,	26° 14′N	66° 19′E	,,
	$t_{4/5}$ S_6 X_6	*Sukkur*	,,	27° 47′N	68° 54′E	,,
	,,	Fort Gouraud	Mauritania	22° 41′N	12° 42′W	,,
	t_5 S_6 X_6	Faya Largeau	Tchad	18° 00′N	17° 10′W	,,
Hot desertic rains without seasonal rhythm	$t_{3/4}$ $S_{5/6}$ X_6	Puerto-Madryn	Argentina	43° 15′S	65° 22′W	Desert
	,,	Las Vegas	Nevada, USA	36° 10′N	115° 10′W	,,
	t_4 S_5 X_6	Alice-Springs	Australia	23° 38′S	133° 37′E	Scrub
	t_4 $S_{5/6}$ X_6	Metlaoui	Tunisia	34° 20′N	8° 22′E	Desert
	,,	Ouled-Djellal	Algeria	34° 25′N	5° 04′E	,,
	,,	*Sibi*	W. Pakistan	29° 33′N	67° 53′E	,,
	,,	*Panjgour*	,,	26° 58′N	64° 06′E	,,
	,,	*Dera Ismail Khan*	,,	31° 49′N	70° 55′E	,,
	,,	Tucson	Arizona, USA	32° 15′N	110° 57′W	,,
	,,	Kalgoorlie	Australia	30° 45′S	121° 3′E	Scrub
	t_4 S_5 X_6	Swakopmund	S.W. Africa	22° 42′S	14° 32′E	Desert

Bioclimate (1)	Value of each ecological factor (2)	Station[1] (3)	Country (4)	Latitude (5)	Longitude (6)	Vegetation (7)
	t_4 s_5 x_6	Mossamedes	Angola	15° 12′S	12° 09′E	Desert
	,,	Tamanrasset	Algeria	22° 50′N	5° 31′E	,,
	,,	Yuma	Arizona, USA	32° 45′N	114° 36′W	,,
	$t_{4/5}$ S_6 X_6	Port Etienne	Mauritania	20° 56′N	17° 03′W	,,
	t_5 S_6 X_6	Aden	Arabia	12° 46′N	45° 3′E	,,
	,,	Lambayeque	Peru	6° 43′S	79° 54′W	,,
Hot-sub-desertic with mediterranean tendency	$t_{3/4}$ S_6 X_5	Krasnovodsk	USSR	40° 09′N	52° 59′E	,,
	$t_{3/4}$ S_6 X_6	*Dalbandin*	W.Pakistan	28° 54′N	64° 26′E	,,
	,,	Zahedan	Iran	29° 30′N	60° 52′E	Semi-desert
	t_4 $S_{5/6}$ X_5	Beersheba	Israel	31° 15′N	34° 43′E	Desert
	t_4 $S_{5/6}$ $X_{5/6}$	Almeria	Spain	36° 50′N	2° 26′W	Steppe
	,,	Baghdad	Iraq	33° 20′N	44° 20′E	Scrub
	,,	Alexandria	UAR	31° 12′N	29° 53′E	Semi-desert
	t_4 $S_{5/6}$ X_6	Broken Hill	Australia	31° 57′S	141° 30′E	Scrub
	,,	Jéricho	Jordan	31° 52′N	35° 28′E	Desert
	,,	O'okiep	S.Africa	29° 36′S	17° 52′E	Scrub
	t_4 S_6 X_6	Punta Tortuga	Chili	29° 55′S	71° 22′W	Desert
	$t_{4/5}$ $S_{5/6}$ $X_{5/6}$	*Ormara*	W. Pakistan	25° 15′N	64° 39′E	,,
	$t_{4/5}$ $S_{5/6}$ X_6	*Pasni*	,,	25° 16′N	63° 28′E	,,
	,,	Iranchere	Iran	27° 13′N	60° 42′E	,,
	t_5 $S_{5/6}$ $X_{5/6}$	Souakin	Sudan	19° 07′N	37° 20′E	Semi-desert
Hot sub-desertic with tropical tendency	$t_{3/4}$ S_5 $X_{5/6}$	*Bannu*	W.Pakistan	33° 00′N	70° 36′E	Dry sub-tropical forest
	$t_{3/4}$ $S_{5/6}$ $X_{,6}$	Santa Maria	Argentina	26° 41′S	66° 40′W	Scrub
	t_4 $S_{4/5}$ X_5	*Agra*	India	27° 10′N	78° 02′E	Thorn forest
	t_5 S_5 X_5	Catamarca	Argentina	28° 29′S	65° 44′W	Scrub
	,,	Fort Tuli	Rhodesia	21° 52′S	29° 12′E	Savanna
	,,	Rehoboth	S.West Africa	23° 19′S	17° 3′E	Scrub
	,,	*Hissar*	India	29° 10′N	65° 44′E	Thorn forest
	t_4 S_5 $X_{5/6}$	*Lyallpur*	W.Pakistan	31° 26′N	73° 04′E	,,
	,,	*Khushab*	,,	32° 18′N	72° 22′E	,,
	,,	Omaruru	S. West Africa	21° 35′S	18° 13′E	Scrub

Bioclimate (1)	Value of each ecological factor (2)	Station[1] (3)	Country (4)	Latitude (5)	Longitude (6)	Vegetation (7)
	t_4 S_5 X_6	*Sri Ganganagar*	India	29° 55′N	73° 53′E	Desert
	,,	*Montgomery*	W.Pakistan	30° 39′N	73° 08′E	Thorn forest
	t_4 $S_{5/6}$ X_6	Arequipa	Peru	16° 22′S	71° 33′E	Desert
	$t_{4/5}$ S_4 X_5	Mazatlan	Mexico	23° 12′N	106° 25′W	Scrub
	$t_{4/5}$ $S_{4/5}$ X_5	*Kotah*	India	25° 11′N	75° 51′E	Thorn forest
	,,	*Ajmer*	,,	26° 27′N	74° 37′E	,,
	,,	*Jaipur*	,,	26° 55′N	75° 50′E	,,
	,,	*Mainpuri*	,,	27° 14′N	79° 03′E	,,
	$t_{4/5}$ S_5 X_5	*Jamnagar*	,,	22° 29′N	70° 04′E	,,
	,,	*Jodhpur*	,,	26° 18′N	73° 01′E	,,
	$t_{4/5}$ S_5 $X_{5/6}$	*Barmer*	,,	25° 45′N	71° 23′E	,,
	$t_{4/5}$ S_5 $X_{5/6}$	*Bikaner*	,,	28° 01′N	73° 18′E	Thorn forest
	,,	*Bhuj*	,,	23° 15′N	69° 48′E	,,
	,,	El-Fasher	Sudan	13° 28′N	25° 21′E	Scrub
	$t_{4/5}$ $S_{5/6}$ X_6	*Hyderabad*	W.Pakistan	25° 23′N	68° 25′E	Thorn forest
	,,	*Badin*	,,	24° 38′N	68° 54′E	,,
	,,	*Karachi*	,,	24° 48′N	66° 59′E	,,
	,,	Kidal	Sudan	18° 26′N	1° 22′E	Semi-desert
	t_5 $S_{4/5}$ X_5	Diourbel	Senegal	14° 50′N	16° 09′W	Savanna
	,,	Baroma	Mozambique	16° 0′S	33° 12′E	,,
	,,	Lome	Togo	6° 07′N	1° 14′E	,,
	,,	Fort Lamy	Tchad	12° 10′N	14° 60′E	,,
	,,	*Deesa*	India	24° 14′N	72° 12′E	Thorn forest
	,,	*Bellary*	,,	15° 09′N	76° 51′E	,,
	t_5 S_5 X_5	Elobeid	Sudan	13° 11′N	25° 21′E	Scrub
	,,	Abécher	Tchad	13° 49′N	20° 51′E	,,
	,,	St. Louis	Senegal	16° 01′N	16° 30′W	Savanna
	t_5 S_5 $X_{5/6}$	Joco-Capelo	Angola	8° 48′S	13° 13′E	,,
	,,	*Dwarka*	India	22° 22′N	69° 05′E	Thorn forest
	,,	Tulear	Madagascar	23° 20′S	43° 41′E	Scrub
	t_5 S_5 X_6	Nouakchott	Mauritania	18° 07′N	15° 56′W	Semi-desert
	,,	Khartoum	Sudan	15° 37′N	32° 33′E	Desert
Hot sub-desertic without seasonal rhythm	$t_{3/4}$ S_5 X_5	Roswell	New Mexico, USA	33° 24′N	104° 33′W	Steppe
	,,	*Fort Sandeman*	W.Pakistan	31° 29′N	69° 27′E	Dry subtropical forest

Bioclimate	Value of each ecological factor	Station[1]	Country	Latitude	Longitude	Vegetation
(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$t_{3/4}$ S_5 $X_{5/6}$	*Miranshah*	W. Pakistan	33° 57′N	70° 07′E	Dry-Sub-tropical forest
	$t_{3/4}$ $S_{5/6}$ $X_{5/6}$	Ain-Sefra	Algeria	32° 45′N	0° 35′W	Semi-desert
	t_4 S_5 X_5	*Lahore*	W.Pakistan	31° 35′N	74° 20′E	Thorn forest
	,,	*Peshawar*	,,	34° 01′N	71° 35′E	Dry sub-tropical forest
	,,	St. Luis-Potosi	Mexico	22° 9′N	101° 01′W	Scrub
	,,	Coolgardie	Australia	30° 57′S	121° 10′E	,,
	t_4 $S_{5/6}$ X_6	Phoenix	Arizona, USA	33° 28′N	112° 0′W	Semi-desert
	$t_{4/5}$ S_5 X_5	Ghinda	Erytrea	15° 26′N	39° 07′E	Scrub
	t_5 $S_{4/5}$ X_5	*Coimbatore*	India	11° 00′N	76° 58′E	Thorn forest
	t_5 S_5 X_5	Bardera	Somalia	2° 30′N	42° 53′E	Scrub
Mediterranean accentuated (7-8 months dry)	$t_{3/4}$ $S_{5/6}$ X_4	El-Kantara	Algeria	31° 13′N	32° 43′E	Semi-desert
	,,	Matmata	Tunisia	33° 37′N	9° 54′E	Scrub
	,,	Teheran	Iran	35° 42′N	51° 25′E	Semi-desert
	,,	Santa-cruz	Argentina	50° 1′S	68° 32′W	Steppe
	$t_{3/4}$ S_5 $X_{4/5}$	*Wana*	W.Pakistan	32° 18′N	69° 44′E	Dry sub-tropical forest
	,,	Dizfoul	Iran	32° 25′N	48° 35′E	Semi-desert
	$t_{3/4}$ $S_{5/6}$ $X_{4/5}$	Deir-es-Zor	Syria	35° 20′N	40° 11′E	Scrub
	,,	*Kalat*	W.Pakistan	29° 02′N	66° 35′E	Dry sub-tropical forest
	,,	*Quetta*	,,	30° 10′N	67° 01′E	,,
	,,	*Chaman*	,,	30° 55′N	66° 28′E	,,
	,,	Fresno	California, USA	36° 41′N	119° 47′W	Semi-desert
	,,	Kerman	Iran	30° 03′N	57° 02′E	,,
	,,	Sarmiento	Argentina	45° 35′S	69° 4′W	Steppe
Tropical accentuated (7-8 months dry)	t_5 S_4 $X_{4/5}$	Soalala	Madagascar	16° 04′S	45° 20′E	Savanna
	,,	Maroua	Cameroons	10° 35′N	14° 20′E	,,
	,,	Kaolack	Senegal	14° 02′N	16° 04′W	,,
		Kayes	Sudan	14° 25′N	11° 34′W	,,
	,,	*Pamban*	India	9° 16′N	79° 15′E	Thorn forest
	,,	Quixeramobim	Brazil	5° 12′S	39° 18′W	Scrub

Bioclimate (1)	Value of each ecological factor (2)	Station[1] (3)	Country (4)	Latitude (5)	Longitude (6)	Vegetation (7)
	t_5 $S_{4/5}$ X_4	*Ahmednagar*	India	19° 05′N	74° 55′E	Thorn forest
	,,	*Sholapur*	,,	17° 40′N	75° 54′E	,,
	,,	*Poona*	,,	18° 32′N	73° 51′E	,,
	,,	*Bijapur*	,,	16° 49′N	75° 43′E	,,
	,,	*Gulburga*	,,	17° 21′N	76° 51′E	,,
	,,	*Raichur*	,,	16° 12′N	77° 01′E	,,
	,,	*Kurnool*	,,	15° 50′N	78° 04′E	,,
	,,	*Gadag*	,,	15° 25′N	75° 38′E	,,
	,,	*Hyderabad* (Dn)	,,	17°26′ N	78°27′ E	,,
	,,	*Miraj*	,,	16° 49′N	74°41′E	,,
	,,	*Rentichintala*	,,	16° 33′N	79° 33′E	,,
	,,	Betioky	Madagascar	21° 30′S	44° 26′E	Scrub
	t_5 $S_{4/5}$ $X_{4/5}$	Matam	Senegal	15° 38′N	13° 13′W	Savanna
	,,	Segou	Sudan	13° 30′N	6° 15′W	,,
	,,	*Dohad*	India	22° 50′N	74° 16′E	Thorn forest
	,,	*Rajkot*	,,	22° 18′N	70° 50′E	,,
	,,	*Veraval*	,,	20°55′ N	70° 22′E	,,
	,,	*Bhavnagar*	,,	21° 45′N	72° 12′E	,,
	,,	*Malegaon*	,,	20° 33′N	74° 32′E	,,
	,,	*Ahmedabad*	,,	23° 02′N	72° 53′E	,,
	,,	*Aurangabad*	,,	19° 53′N	75° 20′E	,,
	t_6 $S_{4/5}$ $X_{4/5}$	Niamey	Nigeria	13° 30′N	2° 06′E	Savanna
Meso-tropical accentuated (7-8 months dry)	t_4 S_4 $X_{4/4}$	*Aligarh*	India	27°53′N	78° 04′E	Thorn forest
	t_4 $S_{4/5}$ X_4	Bulawayo	Rhodesia	20° 9′S	28° 40′E	Savanna
	,,	Monterrey	Mexico	25°40′ N	100° 18′W	Scrub
	,,	Zacatecas	,,	22° 58′N	102° 19′W	,,
	,,	Salta	Argentina	24° 47′S	65° 25′W	,,
	t_4 $S_{4/5}$ $X_{4/5}$	*New Delhi*	India	28° 35′N	77° 12′E	Thorn-forest
	,,	Léon	Mexico	21° 7′N	101° 41′W	Scrub
	t_4 S_5 X_4	Mahalapyá	Bechuanaland	23° 6′S	26° 40′E	,,
	t_4 S_5 $X_{4/5}$	Windhoek	S.West Africa	22° 34′S	17° 12′E	,,

[1] The stations of the Indian sub-continent are in italics.

The Climatological Tables of Observatories in India, World Weather Records—Smithsonian Misc. Publications and *Annales des Services Météorologiques de la France d'Outre-Mer* are the main sources of the climatic data.

It ensues from this Table 1 that the vegetation in the hot desertic climate is predominantly of a desertic type, 30 out of 34 stations possessing this type, the remaining few having semi-desert, scrub or thorn forest. More than half the number of stations in the hot subdesertic climate have either thorn forest (22 stations) or its physiognomically allied type the scrub (17 stations). The difference between thorn forest and scrub is mainly one of the nomenclature. The remaining types are desert, semi-desert, savanna and steppe.

In the mediterranean accentuated climate, there are 5 stations having semi-desert, 4 having dry subtropical forest and 2 each having steppe and scrub. In the tropical and meso-tropical accentuated type there are 21 thorn forest stations, and 8 each of savanna and scrub. The difference in the land-use may account for the existence of thorn forest in India and savanna in Africa under the same bioclimate. In other cases the soils may intervene in deciding the vegetation.

Concluding Remarks

Further work on analogous bioclimates is in progress. It is essential to recognise stable and unstable climates and the variability in the climatic elements of the latter type where the climate of a given year may not be comparable in rainfall amount, régime and distribution to that derived from the figures of averages.

It may also be remembered that bioclimate is only a part of the complete ecology of a species. For the introduction of exotics, a study of the total ecological requirements of the species is indispensable. This includes not only the edaphic factors but also the biotic ones. The vanilla orchid (*Vanilla planifolia* Andrews) when planted in the Reunion Island grew well but did not fructify naturally in the absence of the pollinating insect from its native Central America.

In the framework of climate, the critical factor involved in determining the area of a species may not be an apparent one. For instance, teak (*Tectona grandis* L.f.) has quite a broad amplitude for the rainfall conditions : 750 to 2500 mm. of annual rainfall, length of dry season of 4 to 8 months and mean temperature of the coldest month from 15 to over 20°C ; yet it is absent on the Coromandel coast where conditions well within these amplitudes are obtained. However, the season of occurrence of rains in this belt is quite peculiar (dissymetric) and teak disappears from those regions of southern India where May and/or June rains are very poor (Legris & Meher-Homji 1968).

In the distribution of sal (*Shorea robusta* Gaertn.) the crucial factor is the timely arrival of rains for the germination of seeds which have a very short period of viability. Nursery practices overcome such difficulties in artificial plantations.

Finally, the soil factor may intervene to compensate the climate and may result in imparting a wide distributional range to the species. *Cassia auriculata* L. thrives on the black clayey cotton soils of the semi-arid Deccan where annual rainfall is of the order of 700 mm. with 7 to 8 months dry. In the coastal region of Tamil Nadu with a more humid climate (rainfall over 1000 mm. ; 6 months dry), *C. auriculata* is encountered on the less water retentive sandy loamy soils. *Soymida febrifuga* Juss. occupies wet sites (valleys) in a dry region like Sariska in N.E. Rajasthan ; in humid tracts of Orissa and Bihar it grows on eroded localities. In the mediterranean climate of France, the holly oak (*Quercus ilex* L.) is indifferent in its edaphic requirements but in the wetter atlantic climate it occurs only on calcareous soil which provides a dry substratum, and on warmer southern slopes.

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